Well Integrity in CO_2 Environments Performance & Risk - Technologies

Berkeley
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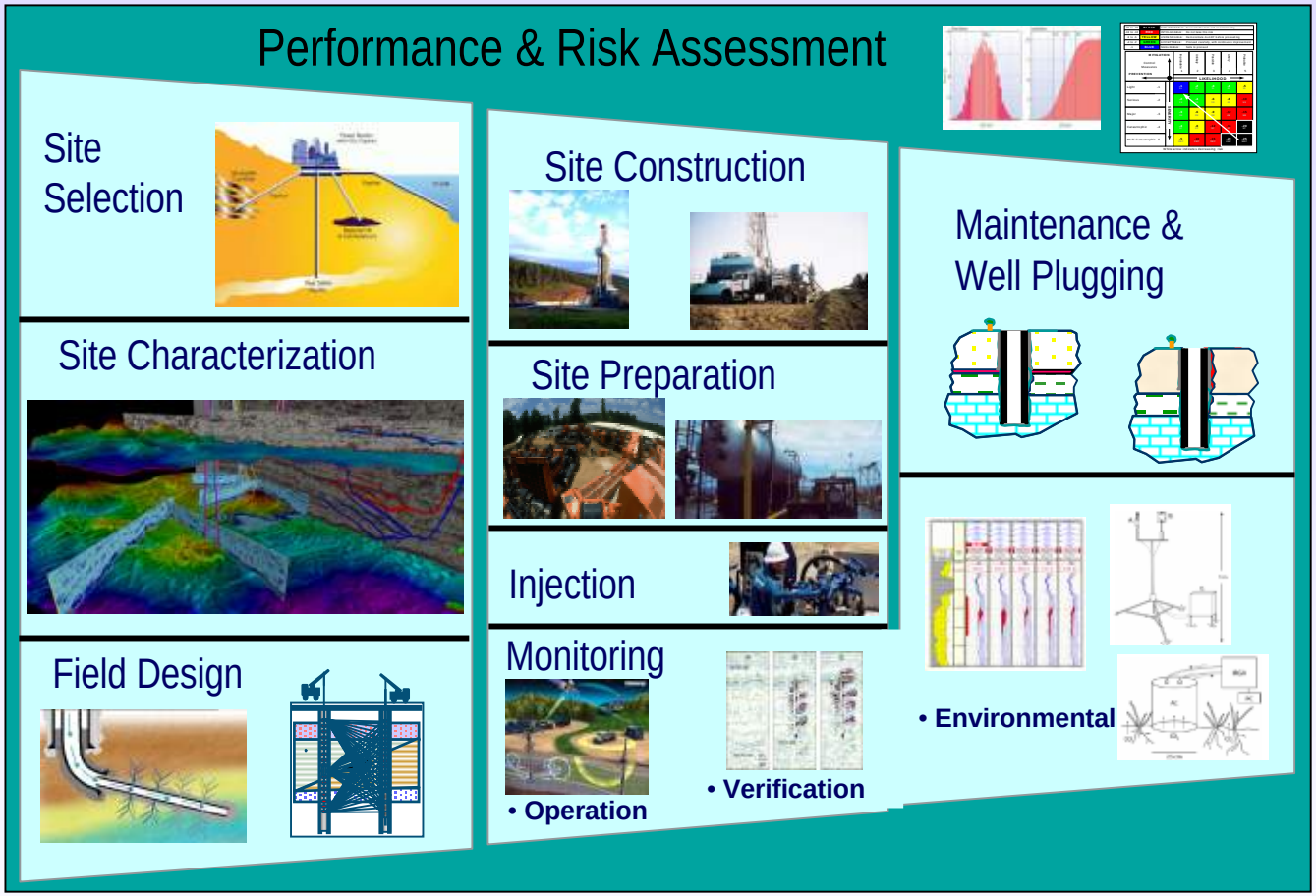
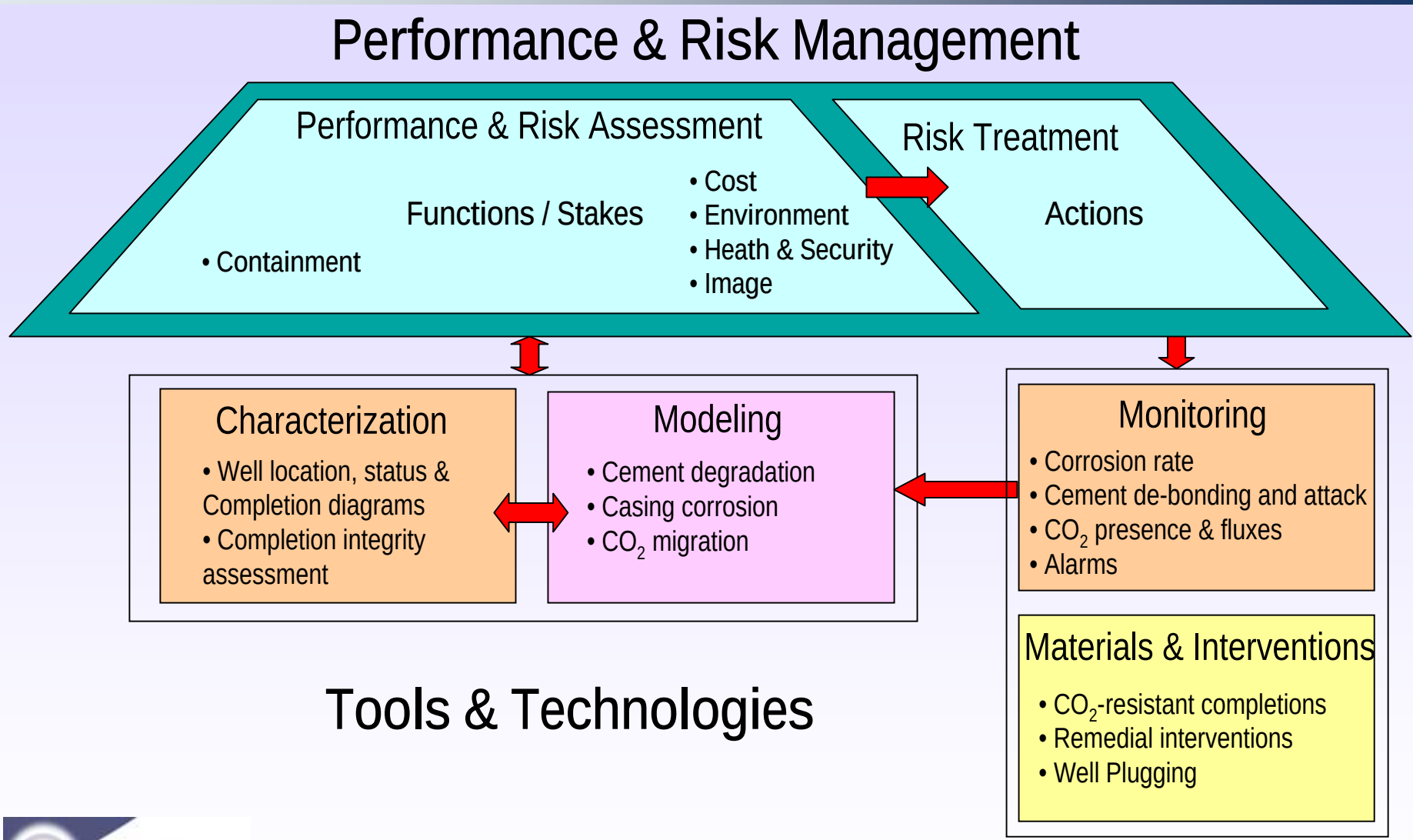
CO_2 Storage Project Timeline

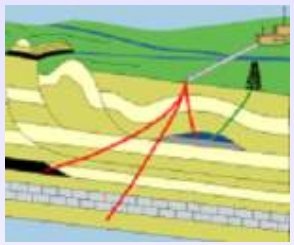


P&R Management Strategy for Well Integrity



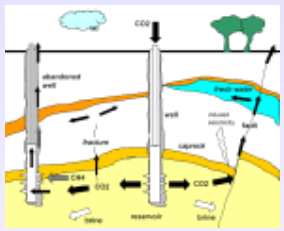
Performance & Risk Assessment - Workflow

Functional Analysis → Construction of Leakage Scenarii → Identification and quantification of failure mechanisms → Risk Ranking & Performance Evaluation

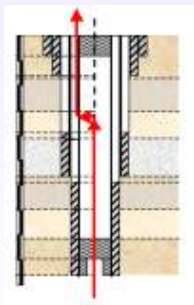


(from US Geological Survey

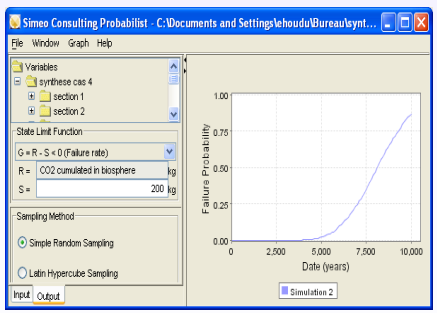
Exhaustive inventory of features and potential hazards

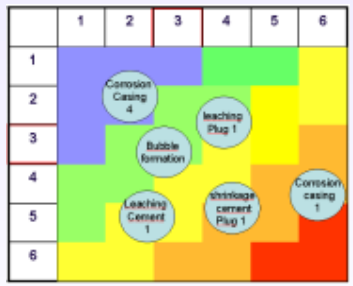


(from Damen et al, 2003)

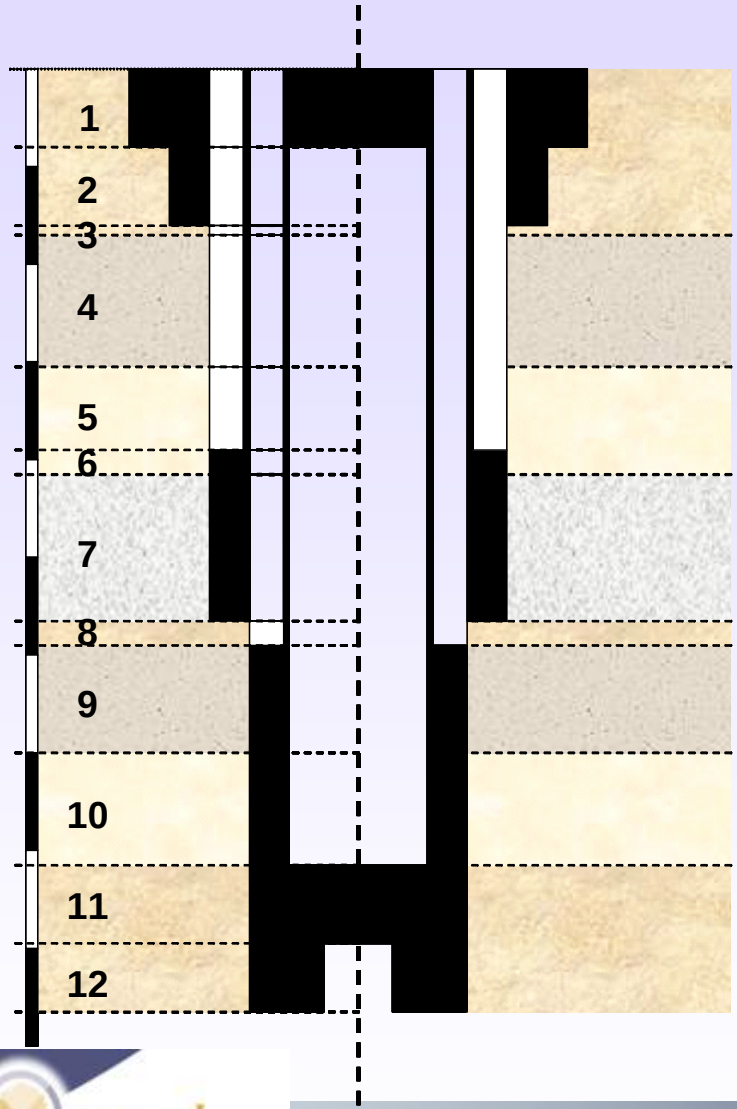


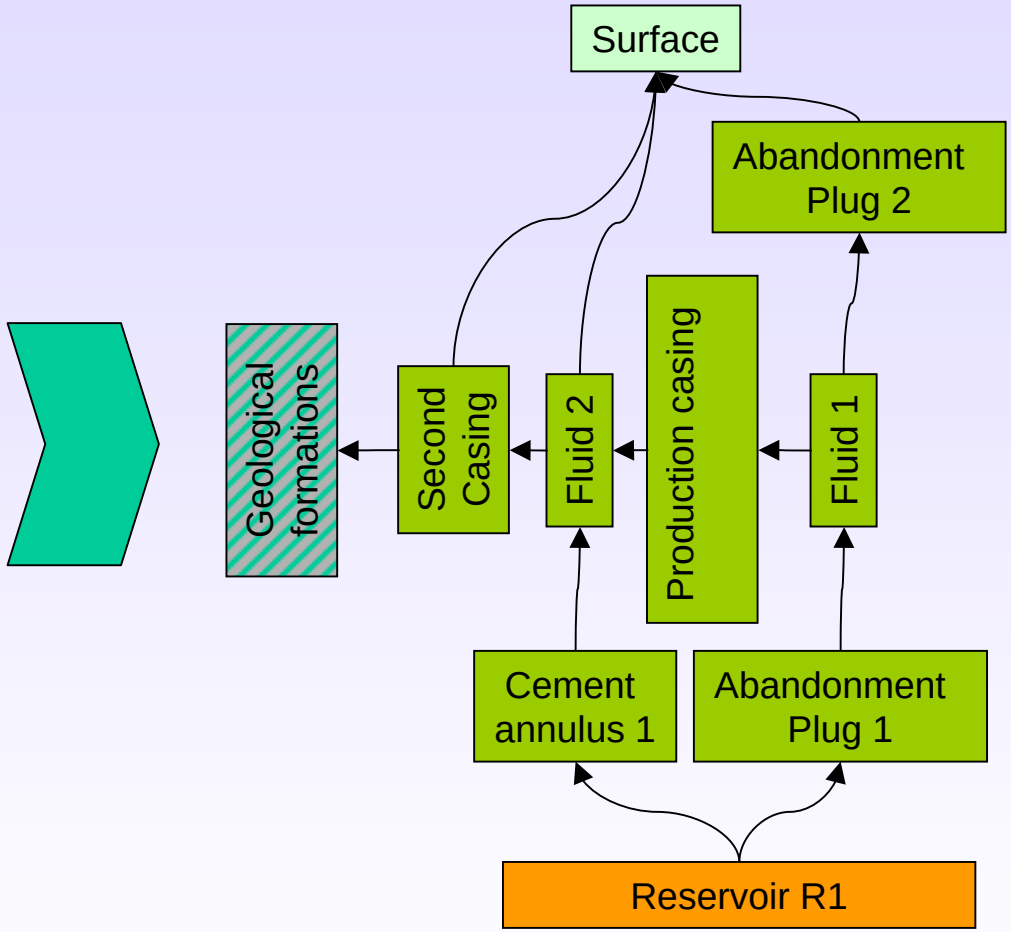
Knowledge
Data & Models
Uncertainties





System Decomposition

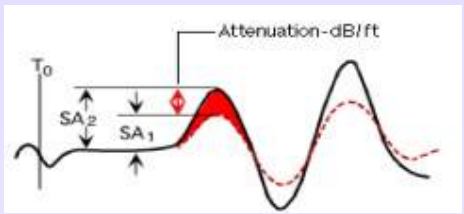


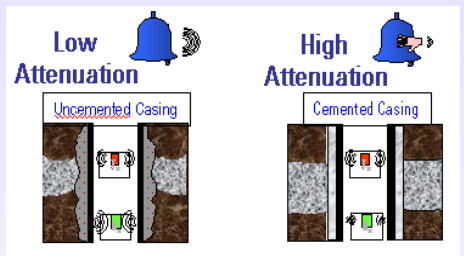


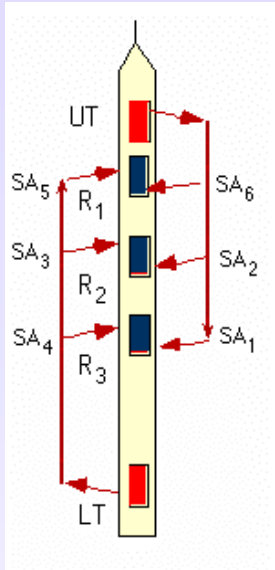
Quantification of failure mechanisms Leakage rates

Well Integrity Measurements

Sonic

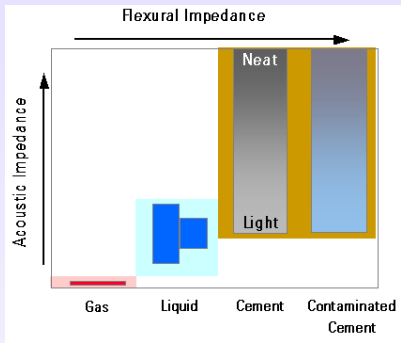


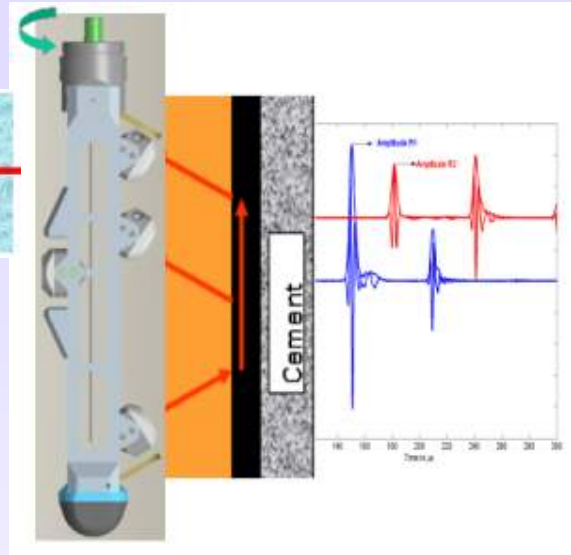




Cement Bond

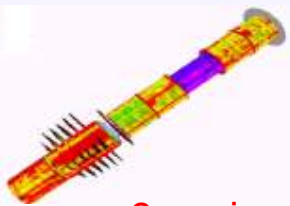
Ultrasonic



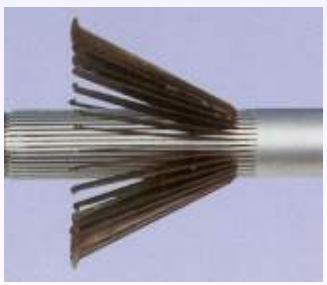


Cement / Corrosion

Multi-finger Caliper

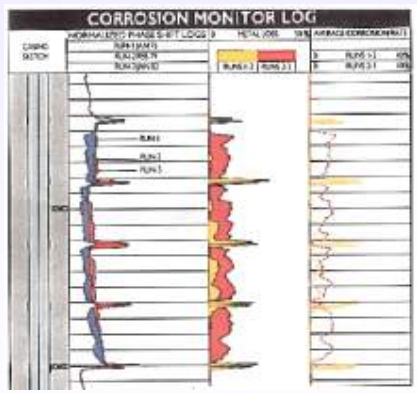


Corrosion



Electromagnetic

Corrosion

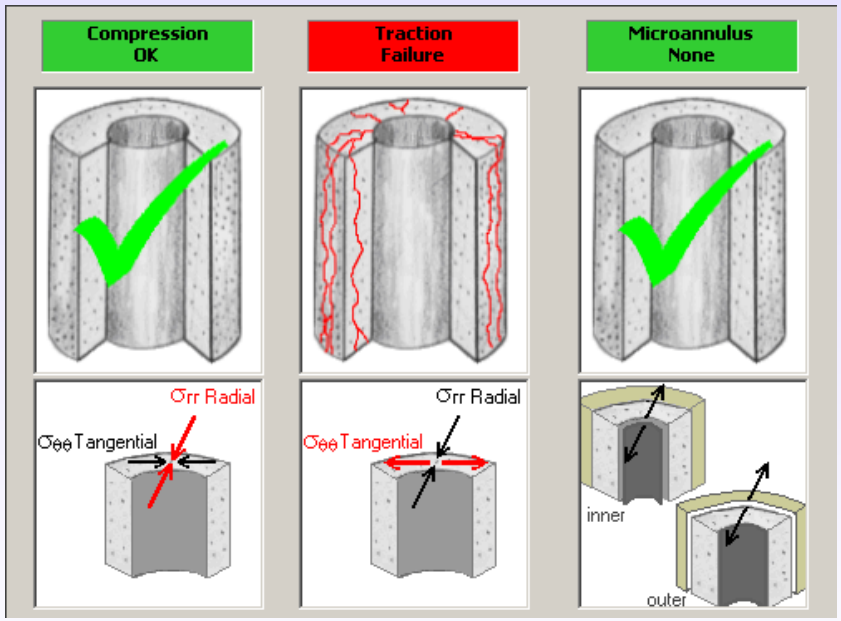


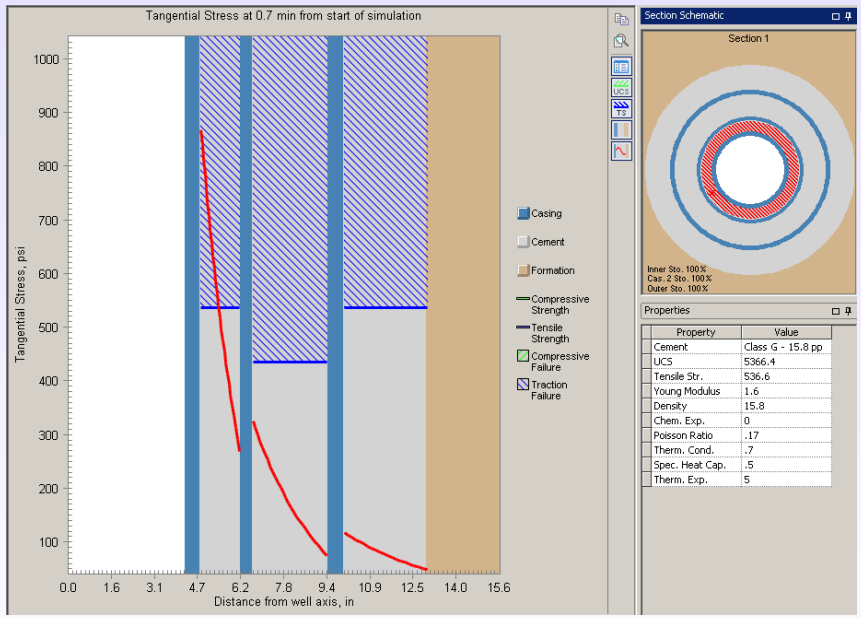
Quantification of failure mechanisms
Leakage rates

Integrity of Completion During Operation

Response of wells to injection operation (effects of P and T variations)

- Micro-annulus
- Fractures in the cement sheath





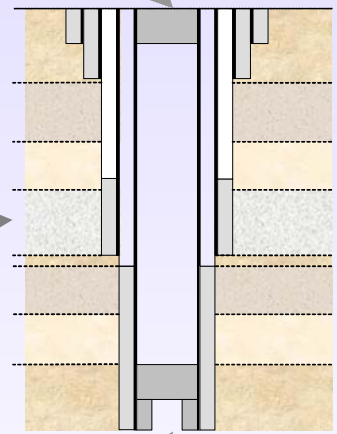
Modeling Degradation and Transport

Cement behavior

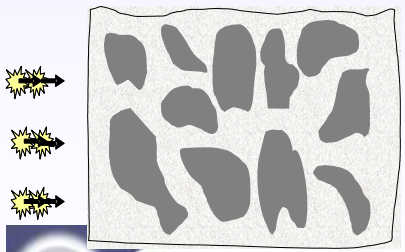
-Cement leaching
-Phase changing
-Reactive porous mechanics
-Physico-mechanical coupling
-Initial state

Steel behavior

-Steel corrosion
-Steel stability
-Steel perforation
-Physico-mechanical coupling
-Micro-Annulus formation

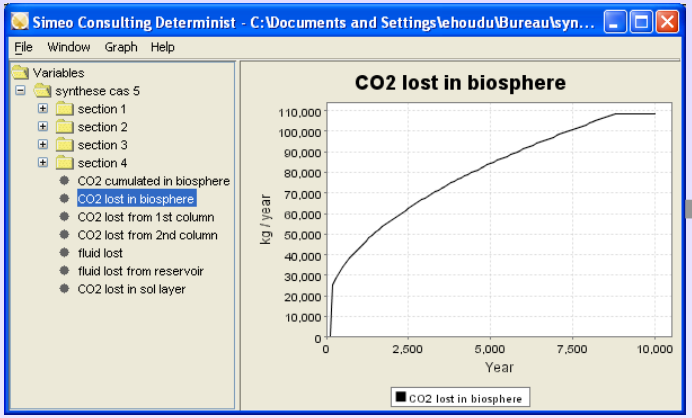


Transport

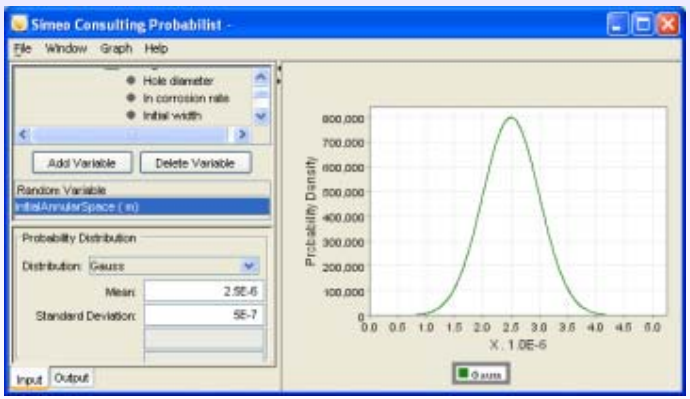


-Transport phenomena (advection + diffusion)
-Gas migration
-Porosity, capillary pressure

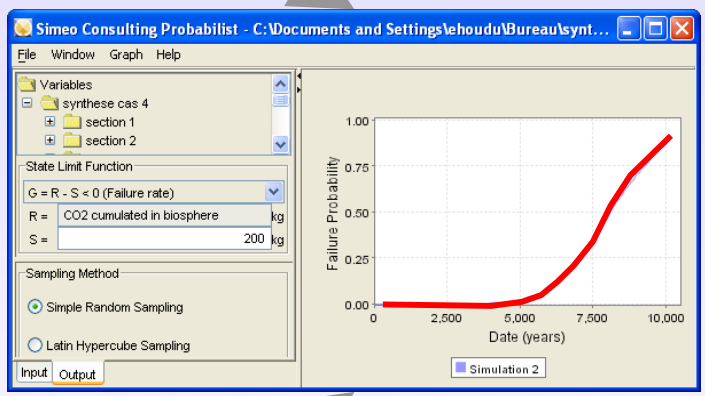
Estimation of Leakage Rates



Deterministic simulation



Probabilistic distribution

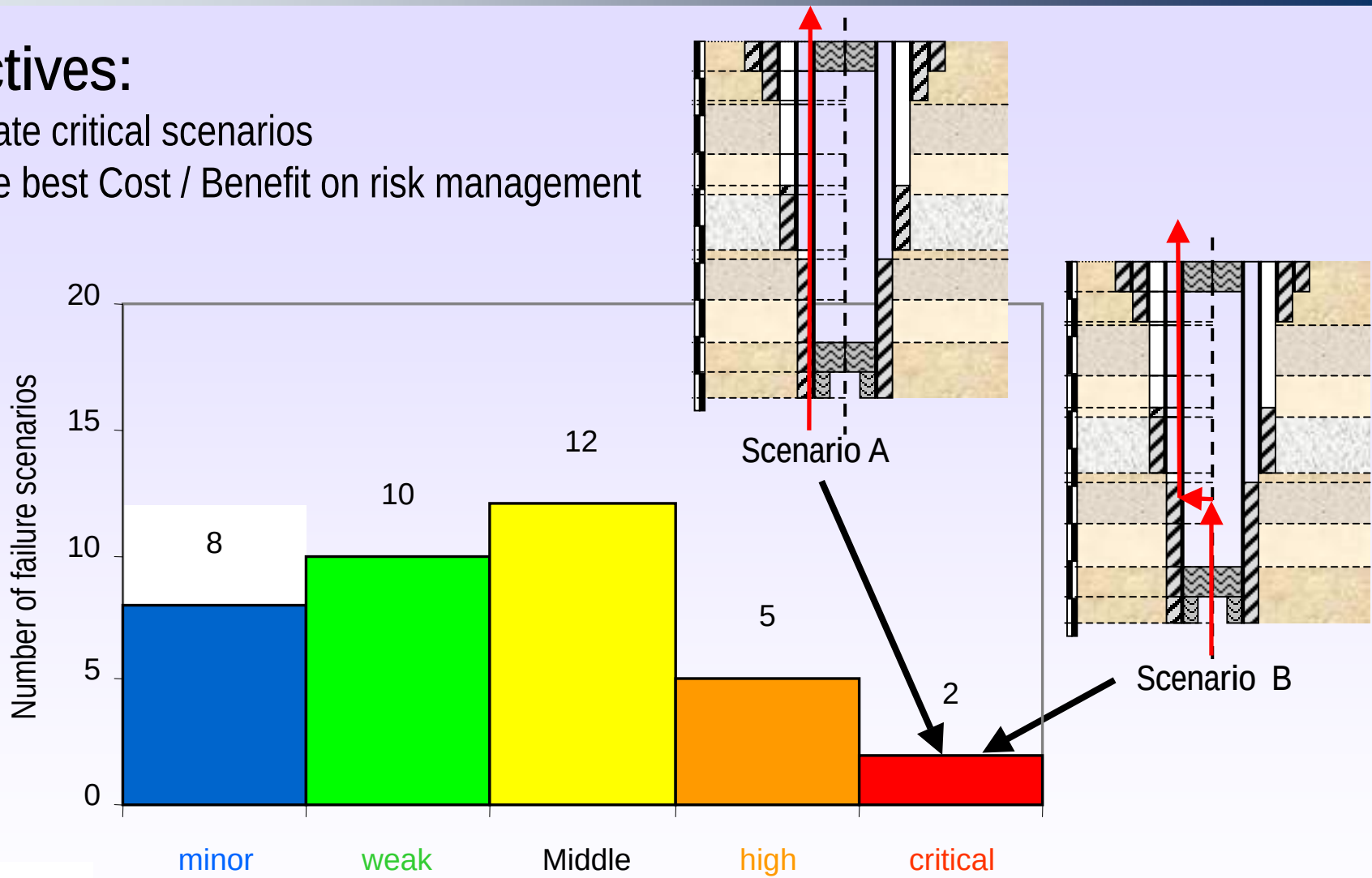


Reliability analysis

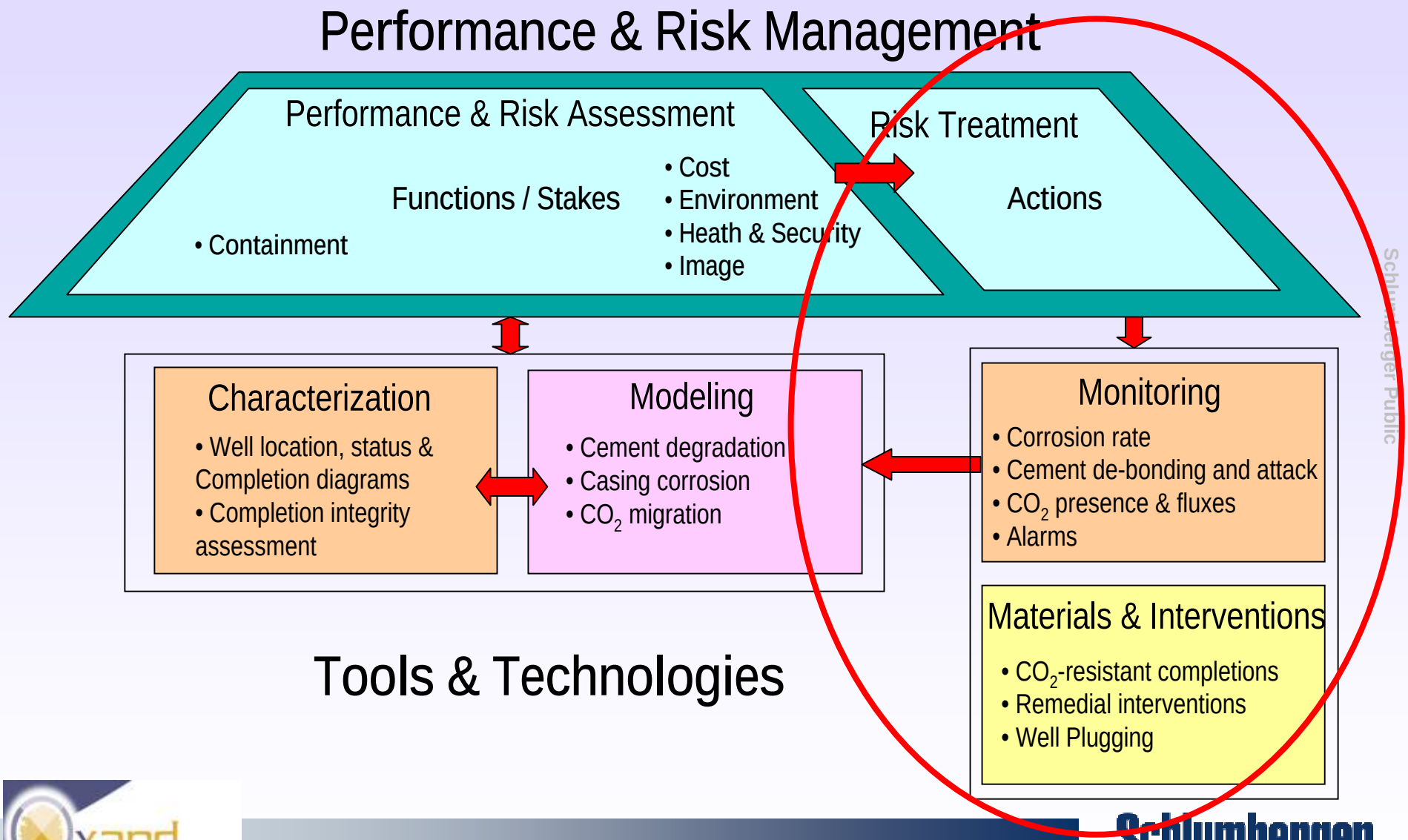
Risk Mapping

Objectives:

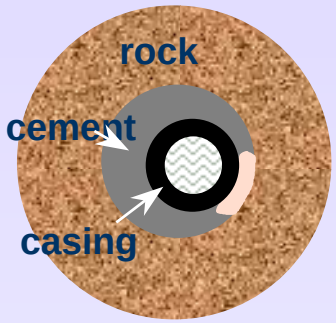
- Eliminate critical scenarios
- Get the best Cost / Benefit on risk management

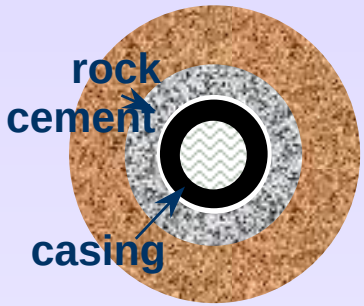


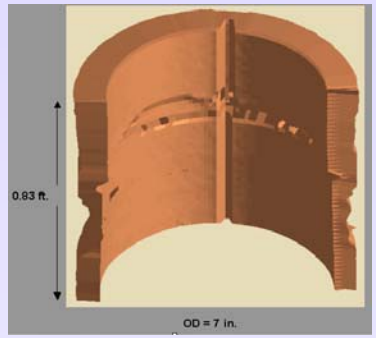
P&R Management Strategy for Well Integrity

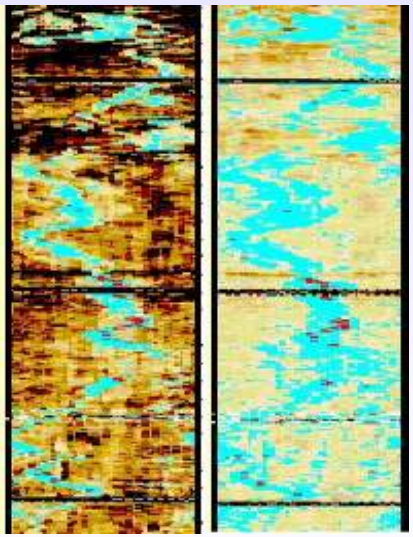


Actions – Monitoring

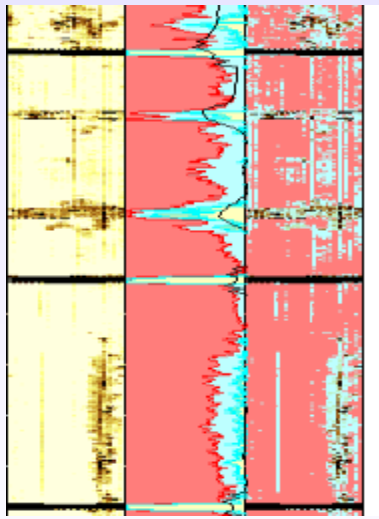




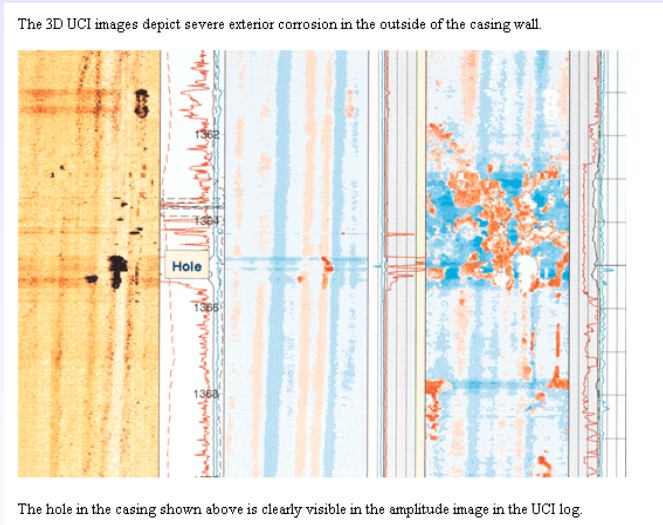




Channeling

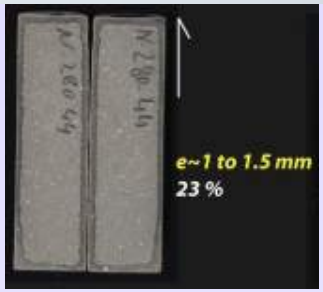


Debonding
steel/cement interface

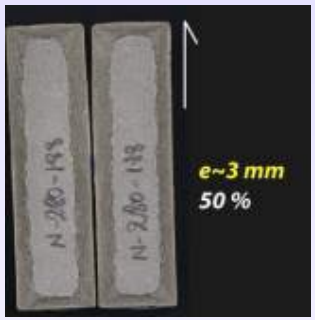


Corrosion

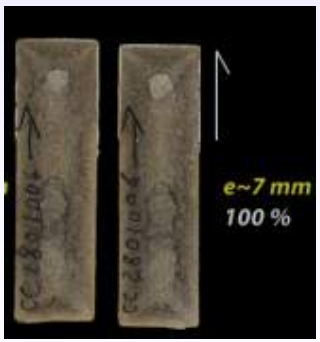
Actions – CO_2-Resistant Materials (Cement)



2 days

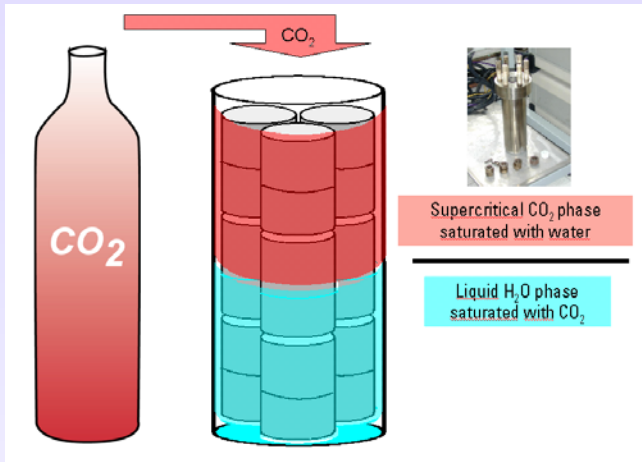


1 week

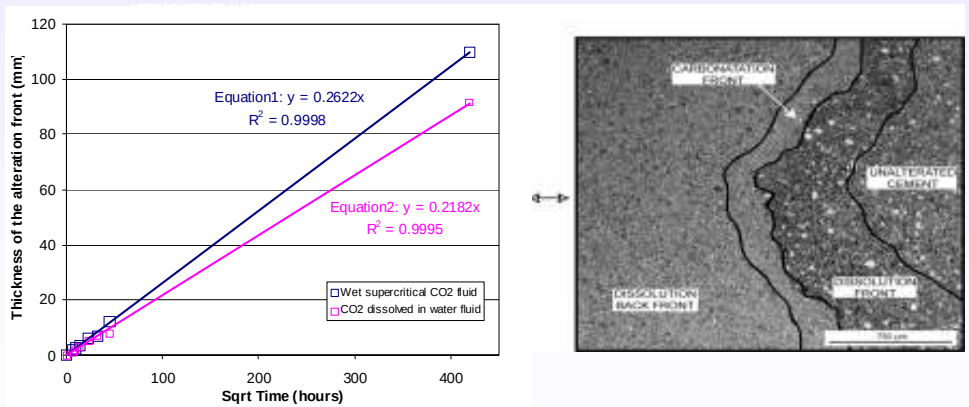


6 weeks

Standard Portland Cements degrade in CO_2 environments



Development of new CO_2-Resistant cements



2 days

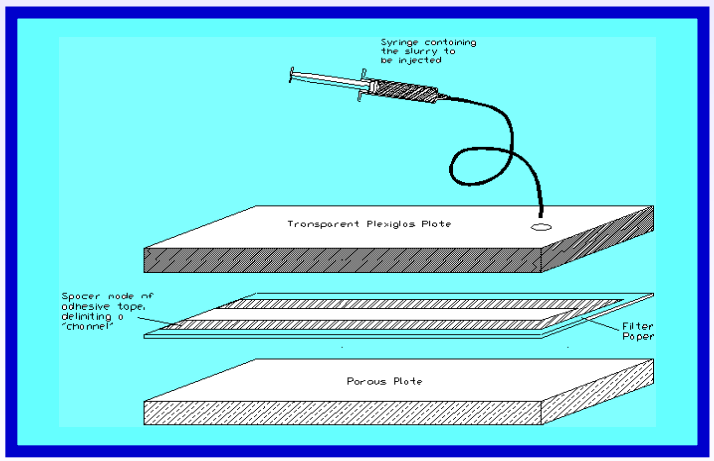
1 week

6 weeks

Actions – Material for Squeeze Jobs

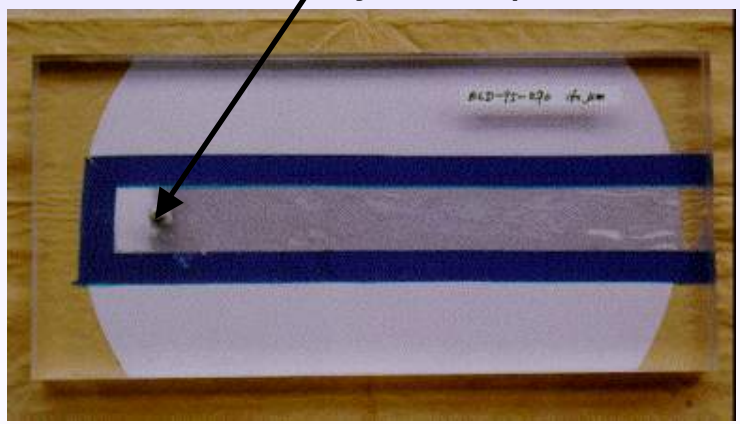
Placement of a special material to seal long and thin discontinuities

- Microannulus
- Channels
- Fractures



Well-dispersed micro-cement

injection point

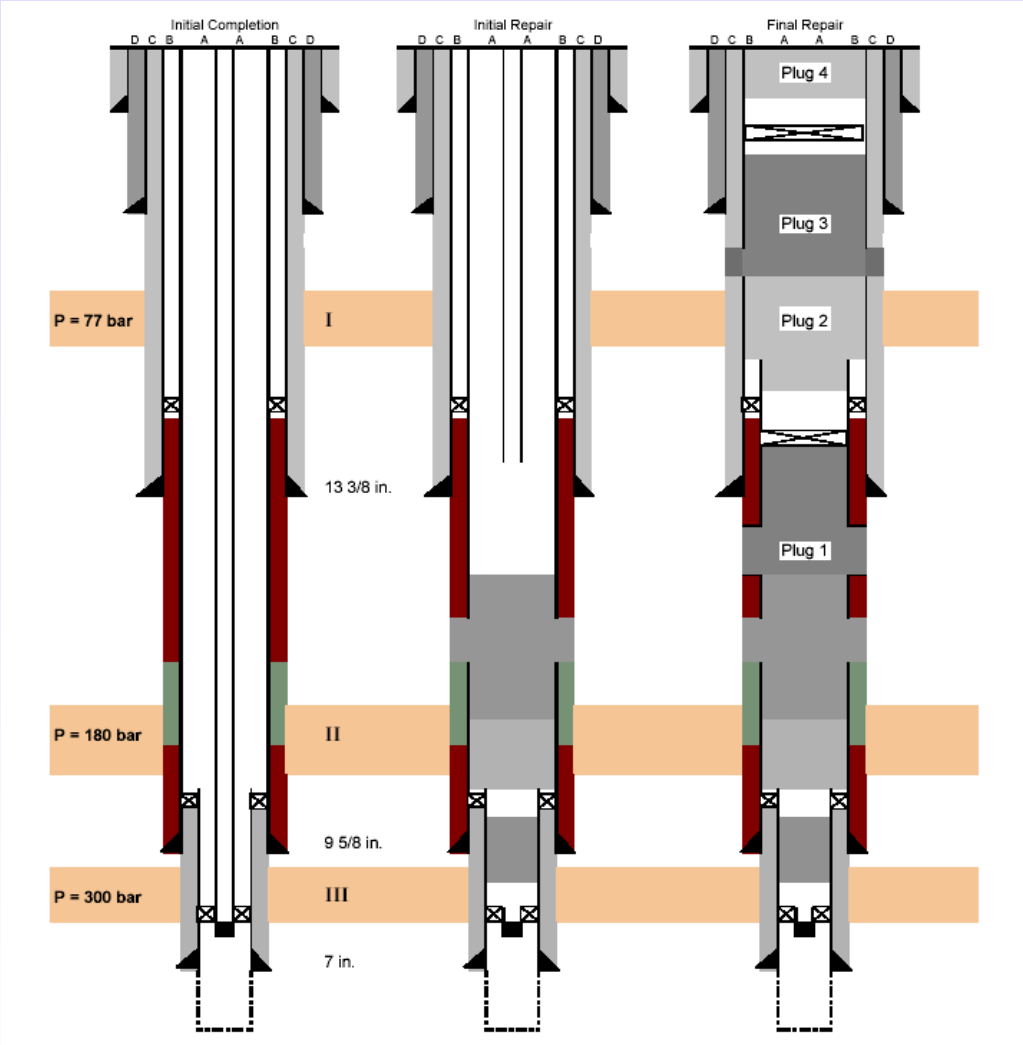


Multimodal slurry

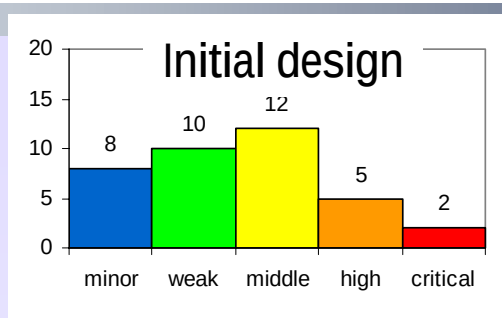
Actions – Well Plugging

Plug design

- Material
- Placement
- Monitoring

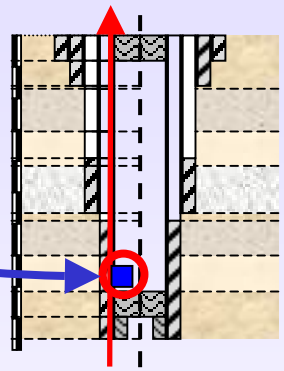


Action Selection – A Guide to Decision



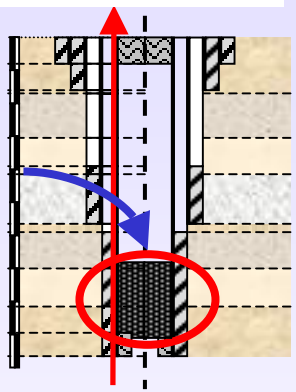
Solution 1:
Monitoring

Cost : 200



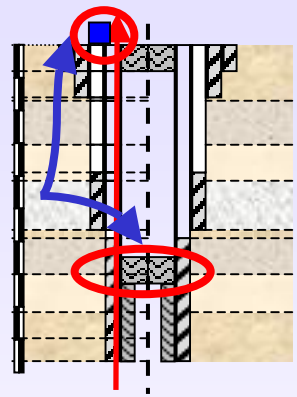
Solution 2:
Thicken plug
Squeeze

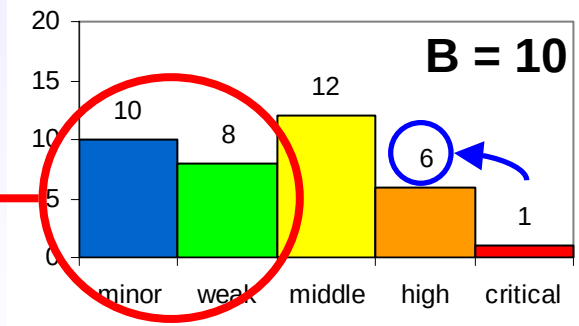
Cost : 600



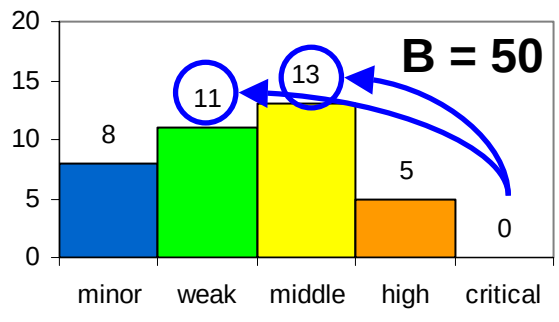
Solution 3:
Change plug position
Improve cement
Surface monitoring

Cost : 300

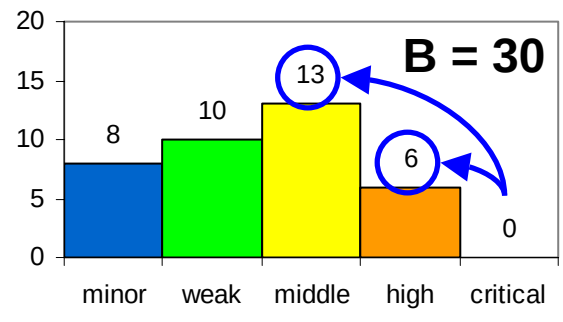




C/B = 20



C/B = 12



C/B = 10

Conclusion

Performance & Risk Management:

- Provides a framework for CO_2 storage control (Safety and Economics)
  - Selection / Evaluation / Closure
  - Cost effective risk management
  - Support for decision making (including P&L, regulations, image)
  - Communication tool
- Requires integrated tools
  - An assessment methodology
  - Modeling tools
  - Characterization and Monitoring Measurements
- Applies to Well Integrity and beyond